Environmental carrying capacity assessment of industrial growth center region

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Abstract. Sustainable economic development, especially the industrial sector, is an important agenda in improving the welfare of the population. The problem that arises is that land use for industry is dominant compared to considerations of the carrying capacity. This study aims to analyze the carrying capacity of the environment, especially land and water in the industrial growth center region (WPPI) South Riau. This study will quantify the potential of WPPI and its impact on the environment using the ECC approach. Data analysis was carried out using quantitative and descriptive analysis methods. Quantitative method is used to analyze the carrying capacity of the environment and descriptive method is used to analyze the recommendations resulting from the calculation of the carrying capacity of the environment. The land for the development of industrial areas is mainly peat domes and marine. The status of the carrying capacity of the land experienced a deficit, namely the regencies of Indragiri Hilir, Indragiri Hulu and Kuantan Singingi. The need for raw water/clean water in industrial growth centers reaches 3,758 liters/second. The land carrying capacity in the study area is dominantly low and the water carrying capacity is very low.

1 Introduction

Riau is a province in Sumatra that accelerates industrial growth to achieve the welfare of its population. The manufacturing industry of Riau Province has increased in value and proportion, from 33.78% in 2010 to 36.92% in 2020. The population working in the industrial sector reaches 7.85%. The center of industrial growth can increase welfare, economic standards, and employment [1]. One area that is directed to become an industrial center in the southern part of Riau is Indragiri Hilir Regency and its surroundings.

One aspect of development that causes changes in land use is by starting to prepare the industrial growth center area (WPPI). The problem is that the interests of land use are more dominant than the consideration of land use's carrying capacity. As a result,
land use may exceed its capacity. The impact is in the form of degradation of the physical quality of the land and pollutants [2].

The classic debate about regional economic development is always related to environmental sustainability [3]. Environmental carrying capacity is the ability to support humans and other living things and the balance between the two. Environmental carrying capacity (ECC) can be understood as “a concept and tool for sustainable development of human settlements; (...) a threshold level of anthropopressure, which the environment can balance and withstand without irreversible changes and serious degradation” [4].

The scope of the application of carrying capacity has been expanded, such as the carrying capacity of land resources [5], carrying capacity of water resources [6], environmental carrying capacity [7], ecological carrying capacity [8], social carrying capacity [9] and overall carrying capacity [7, 10]. The development of carrying capacity gradually emphasizes the importance of the influence of human activity factors on carrying capacity. The object of evaluation gradually shifts from a single element of resources and environment to the carrying capacity for multiple or comprehensive elements [11].

The characteristics of an area are the basis needed to determine whether these needs are adequate with the ecological carrying capacity [12]. Assessing the environment’s carrying capacity can be based on land capability, water availability, investment in environmental protection [13], population distribution, economic improvement, and quality of life [14]. The carrying capacity of resources and the environment is the foundation of sustainable development [15].

Changes in spatial planning become a problem as a result of development activities. With these spatial changes, the condition of the ecological environment of an area will be affected. All production and consumption activities always produce waste. Waste that exceeds the natural absorption capacity creates ecological problems [16]. The results of previous research studies provide an understanding that in WPPI south of Riau, it is necessary to conduct studies regarding the carrying capacity of land resources, water resources, environment, ecology, and society. This study aimed to analyze the aspects of soil and water-carrying capacity in WPPI. This research is helpful for the government as a basis for policy-making in spatial planning [16]. The results of previous research studies provide an understanding that in WPPI south of Riau, it is necessary to conduct studies regarding the carrying capacity of land resources, water resources, environment, ecology, and society. This study aimed to analyze the aspects of soil and water-carrying capacity in WPPI. This research is helpful for the government as a basis for policy-making in spatial planning.

2 Methodology

This study will quantify the potential of industrial development and its impact on the environment using the ECC approach. This study analyzes the environmental carrying capacity of the industrial area in Indragiri Hilir Regency by looking at two main elements, namely the carrying capacity of land and water. Research locations are selected based on
the complexity of industrial activities and scale. The water demand in the study area is higher than the supply, and this causes a water-carrying capacity deficit.

ECC assessment at the local level requires the most recent year for which most statistical data are available [11]. The data for the analysis were obtained from various sources: national databases, local government units, scientific articles, or reports. Then, data analysis was carried out using quantitative and descriptive analysis methods. Quantitative methods are used to analyze the environment’s carrying capacity by using mathematical formulas. While the descriptive method is used to analyze the recommendations resulting from calculating the environmental carrying capacity. The formula used to calculate the carrying capacity of the environment is as follows: Land resources carrying capacity \( \left( LCCB \right) = \frac{\alpha LW}{LT_b} \), in which \( LW = \) extent of land (ha), \( \alpha = \) coefficient of maximum extent of built-land, and \( LT_b = \) extent of built-land (ha). Water resources carrying capacity \( \left( WCC \right) = \frac{SW}{DW} \), in which \( SW = \) water availability and \( DW = \) water demand.

The analysis of the carrying capacity of the land used is the analysis of the carrying capacity of the land based on the total production value. The comparison is the availability of land and the need for land to meet the needs of regional biological products following the Regulation of the State Minister of the Environment Number 17 of 2009.

### 3 Results and discussion

#### 3.1 Land carrying capacity

Most of the area (80%) in Indragiri Hilir Regency has a soil structure in the form of organosol soil (histosol), namely peat soil that contains much organic matter (see Table 1). The peat soil layer reaches a thickness of more than 10 cm. This soil is dominant in the lowlands between river flows. This type of soil originates from the accumulation of humus on the forest surface, which decomposes on the soil surface. In Indragiri Hilir Regency, this type of soil is evenly distributed in almost all sub-districts.

<table>
<thead>
<tr>
<th>No</th>
<th>Land unit</th>
<th>Area (ha)</th>
<th>%</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Marine</td>
<td>198,346.03</td>
<td>17.09</td>
<td>Generally slope &lt; 3% and a small part &lt; 8%</td>
</tr>
<tr>
<td>2</td>
<td>Peat Dome</td>
<td>874,161.66</td>
<td>75.32</td>
<td>Dominated by freshwater oligotrophic with a depth of &gt; 2 meters</td>
</tr>
<tr>
<td>3</td>
<td>Alluvial</td>
<td>6,615.40</td>
<td>0.57</td>
<td>Generally slope &lt;3%</td>
</tr>
<tr>
<td>4</td>
<td>Plain</td>
<td>49,325.37</td>
<td>4.25</td>
<td>Generally slope &lt;3% in the southern part of the region</td>
</tr>
<tr>
<td>5</td>
<td>Hills</td>
<td>32,148.54</td>
<td>2.77</td>
<td>Generally slope 16-25% in the southern part of the region</td>
</tr>
</tbody>
</table>

Source: Bapedalda and PKSPL-IPB, 2021.
Plantations and secondary mangrove forests dominated land cover in the southern region of Riau in 2015, and this is because all the locations of regional activity centers are in coastal areas (detailed in Table 2).

Table 2. Land cover in WPPI South Riau.

<table>
<thead>
<tr>
<th>No.</th>
<th>Land cover in WPPI South Riau</th>
<th>Ha</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Secondary mangrove forest</td>
<td>1,862.34</td>
<td>3.72</td>
</tr>
<tr>
<td>2</td>
<td>Plantation</td>
<td>46,998.20</td>
<td>93.80</td>
</tr>
<tr>
<td>3</td>
<td>Settlement</td>
<td>56.98</td>
<td>0.11</td>
</tr>
<tr>
<td>4</td>
<td>Open ground</td>
<td>31.15</td>
<td>0.06</td>
</tr>
<tr>
<td>5</td>
<td>Water body</td>
<td>1,158.08</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>50,106.75</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Source: Bapedalda and PKSPL-IPB, 2021.

### 3.2 Water carrying capacity

Large rivers generally have a brown watercolor because they are swamp water that comes from flood and tidal overflows trapped in back swamps and several basins in floodplains and coastal areas. The Indragiri River, with a length of 550 km, has a maximum discharge of 7,659 (min. 291), and the Kateman River, with a length of 100 km, has a maximum discharge of 140 (min. 15.24).

Groundwater found in shallow aquifers (free groundwater) is generally at a depth of 3-5 m below the local soil surface and is acidic, cloudy, and reddish. The quantity is strongly influenced by the season—surface water. Water is generally slightly brownish, slightly cloudy to cloudy, odorless, tasteless to salty, and pH ranges from 5.8 to 7.1. The presence of seawater intrusion into river water is estimated to reach as far as 30 km from the coastline. River water and ditches are not used directly, especially for drinking water, because the water quality does not meet the water quality standards.

The important thing that becomes a weakness of surface water is its quality. All river water in Indragiri Hilir is not suitable for direct use. The rivers are dirty, especially in the downstream, so they cannot be used for various household needs (Table 3). In rural areas there are many streams from rivers which are not suitable for direct human use and water from other sources needs to be boiled before consumption. Most of the contamination of the river comes from industrial and domestic waste that goes directly into the river.

The land allocated for the industrial growth center in Indragiri Hilir Regency is 5,203.95 ha, of which 105 ha currently exists. The status of the carrying capacity of the land is obtained from a comparison between land availability (SL) and land demand (DL); if SL > DL, the carrying capacity of the land is declared surplus. If SL < DL, the land’s carrying capacity is declared deficit or exceeded. Based on the analysis of BAPPEDA Riau Province (2013), the distribution of land carrying capacity in Riau Province is very
diverse. Districts experiencing a deficit are Indragiri Hilir District (-59.319), Indragiri Hulu Regency (-61.452), Kuantan Singingi Regency (-9.163).

Table 3. Environmental carrying capacity.

<table>
<thead>
<tr>
<th>No.</th>
<th>Land</th>
<th>Ha</th>
<th>(%)</th>
<th>Water</th>
<th>Ha</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Very Low</td>
<td>8.81</td>
<td>0.18</td>
<td>Very Low</td>
<td>4,894.87</td>
<td>97.69</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>4,524.07</td>
<td>90.29</td>
<td>Low</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Medium</td>
<td>251.87</td>
<td>5.03</td>
<td>Medium</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>High</td>
<td>225.92</td>
<td>4.51</td>
<td>High</td>
<td>115.81</td>
<td>2.31</td>
</tr>
<tr>
<td>5</td>
<td>Very High</td>
<td>-</td>
<td>-</td>
<td>Very High</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>5,010.67</td>
<td>100.00</td>
<td></td>
<td>Total</td>
<td>5,010.67</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Estimating water needs to meet water for the industrial sector, especially in the area. Raw water is the primary input for industrial development, used in various industrial activities. Adequate water supply increases industry efficiency and competitiveness. Groundwater must be maintained to ensure the supply of raw water. Therefore, the use of raw water must be sustainable and according to standards.

Fig. 1. Indragiri river basin.
The current use of raw water at WPPI generally uses surface water, especially by utilizing watersheds. The basis for calculating industries' water needs is based on each industry's production capacity. The industrial raw water, as mentioned above, comes from the water management installation of the company in the area concerned. Raw water needs to support WPPI South Riau by utilizing surface water sources from the Pinang Besar River, Pinang Kecil River, and Perigi River as raw water sources (Figure 1).

Along with the development of the Kuala Enok Port, port activities and industrial areas around the Kuala Enok Port area will increase. One of the indispensable needs is a source of clean water. This clean water facility will later be supplied for ships, ports, and industrial areas with a projected daily demand of 5000 tons/day.

WPPI development is planned for Kuala Enok to be the center with 5,010.67 ha. Based on the Regulation of the Minister of Industry of the Republic of Indonesia No. 35/M-IND/PER/3/2010 concerning Technical Guidelines for Industrial Estates, clean water must be provided in 0.55 – 0.75 liters/second/ha. This area needs raw water/clean water at 3,758 liters/second.

### 3.3 Accessibility

The coast of the coastal area of Indragiri Hilir Regency is a sedimentation area originating from river sediments and marine alluvials. The coastal plain has a smooth relief with a flat slope where the slope is less than 5 percent, which makes it an intertidal zone. The depth of the shipping channel published by the Hydro-Oceanographic Service of the TNI-AL is no longer suitable for the seaward channel from the mouth of the river, where the depth of the channel is about 12 meters. At the same time, it is about 10 meters in the middle.

Indragiri Hilir has ports in Kuala Enok and Tanah Merah districts. The availability of this infrastructure has made Indragiri Hilir a connecting area of Riau with other
provinces. The development of the airport has been included in the Indragiri Hilir Regency planning. Based on the availability of such infrastructure, a logistics system can be developed (Figure 2). However, to increase support for WPPI development, the availability of infrastructure needs to be increased. Among them are road development and port capacity development to accommodate large ships.

4 Conclusion

The land for developing industrial areas is mainly peat domes and marine. The status of the carrying capacity of the land experienced a deficit, namely in the districts of Indragiri Hilir (-59.319), Indragiri Hulu (-61.452), and Kuantan Singingi (-9.163). The need for raw water/clean water in industrial growth centers reaches 3,758 liters/second. The land-carrying capacity in the study area is dominantly low, and the water-carrying capacity is shallow. The depth of the shipping lane from the estuary to the sea is about 12 meters. The depth in the middle is about 10 meters.

Community support is needed in the form of the willingness of some people affected by regional development. Good regulation and supervision following the principles of environmental sustainability will strengthen the environmental carrying capacity in the industrial center area.

References

5. N. Yang, J. Li, B. Lu, M. Luo, L. Li, Sustainability 11, 2786 (2019)